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EFFECTIVENESS OF THE PROPRIOCEPTIVE NEUROMUSCULAR FACILITATION METHOD APPLICATION ON UPPER LIMB FUNCTIONS IN PATIENTS AFTER STROKE: A SYSTEMATIC REVIEW OF LITERATURE

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Abstract. *The brain damage caused by a stroke can lead to severe and long-lasting physical and mental health problems, which can have a significant impact on human quality of life. Although restoring gait parameters in stroke patients is one of the most important rehabilitation goals, currently around 80% of stroke survivors have some degree of upper limb motor impairment. Several authors have shown that restoration of upper limb function is often more difficult to achieve and requires a longer rehabilitation period. Proprioceptive neuromuscular facilitation (PNF) is thought to be one of the most common neurophysiological techniques used by physiotherapists in post-stroke rehabilitation. The aim is to evaluate the effectiveness of proprioceptive neuromuscular facilitation (PNF) in improving upper limb function in patients after stroke through a systematic literature review. The research inquiry was performed by searching through various online databases until February 2023. Following the PRISMA 2020 guidelines, studies were selected using the PICO model and its elements, and based on the inclusion and exclusion criteria. The quality of the selected studies was assessed using the PEDro scale. The review examined five studies on PNF effects in 210 stroke patients, all scoring six or more on the high-quality PEDro scale. Patients were, on average, 52 to 63 years old. Four of the five studies, using the Arm Motor Ability Test and Fugl-Meyer assessment, showed statistically significant improvements in upper limb motor ability and function post-PNF intervention. One study assessing self-care functional ability revealed significant improvements in the Barthel index for both experimental and control groups. Spasticity assessment with the Ashford scale in one study indicated a statistically significant reduction in upper limb spasticity in both groups. Yeole et al. found significant improvements in active range of motion using a manual goniometer in shoulder and elbow joints and wrist joint flexion, extension, and radial deviation for PNF-applied participants.*
Keywords*: proprioceptive neuromuscular facilitation, rehabilitation, stroke, upper limb.*

Introduction

Stroke is defined as a clinical syndrome characterized by an acute, focal neurological deficit caused by damage to the blood vessels of the central nervous

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system, or by an infarction or hemorrhage. According to data published by the World Health Organization, stroke is the second leading cause of death and the third leading cause of disability worldwide (Murphy & Werring, 2020; Singh, 2021).

Globally, 15 million people suffer from stroke each year, while 5 million becoming permanently disabled with hemiparesis, spasticity and other disorders that impair the quality of life of victims, and in 2017 stroke was among the top five causes of disability in high-income countries and worldwide (Nogueira et al., 2021; Clery, Bhalla, Rudd, WolfeI & Wang, 2020).

People may develop cognitive and motor impairments after a stroke, as well as sensory impairments, somatosensation, balance, and coordination problems. Although restoring gait parameters in stroke patients is one of the most important rehabilitation goals, currently around 80% of stroke survivors have some degree of upper limb motor impairment. Ingram et al (2021) show that restoration of upper limb function is often more difficult to achieve and requires a longer rehabilitation period (Ingram, Butler, Brodie, Lord & Gandevia, 2021).

In 2013, it was estimated that 900,000 people in the UK were living with the effects of a stroke. Approximately 70% of these people will have altered hand and arm function, and 40% will be left with permanent limitations in upper limb function (Purton, Sim & Hunter, 2021).

Upper limb impairment compromises reaching, grasping, and other skills, partially or completely interfering with activities of daily living and reducing an individual's quality of life (Nogueira et al., 2021).

Neurorehabilitation techniques aim is to develop neuroplasticity and help restore motor function. Proprioceptive neuromuscular facilitation (PNF) is thought to be one of the most common neurophysiological techniques used by physiotherapists in rehabilitation after a stroke. Although less studied compared to other rehabilitation methods such as mirror therapy and virtual reality, recent studies have shown that PNF is one of the effective physiotherapy methods that facilitate stroke patients' recovery and can effectively improve upper limb function (Tanabe et al., 2016). However, to date, based on the available information, no systematic review can be identified that investigated the effect of the PNF technique in improving upper limb function in patients after stroke.

The aim of this study is to evaluate the effectiveness of proprioceptive neuromuscular facilitation (PNF) in improving upper limb function in patients after stroke through a systematic literature review.

Research objectives: Following the PRISMA 2020 guidelines, using the PICO (Population, Intervention, Comparison, and Outcomes) model and its elements, and based on the inclusion and exclusion criteria, to select studies on the effectiveness of the proprioceptive neuromuscular facilitation method in improving upper limb function in patients after stroke; Assess the quality of the selected studies using the PEDro (Physiotherapy Evidence Database scale)

criteria; Summarise and analyse in a structured way the results of the studies on the effectiveness of the proprioceptive neuromuscular facilitation method in improving upper limb function in patients after stroke.

Literature review

Proprioceptive neuromuscular facilitation is a treatment concept pioneered by Dr Herman Kabat in 1940, mainly used for orthopedic and neurological patients (as well as other types of patients). The PNF technique is based on the principles of motor control and its evolution, as well as neurophysiology; the focus is mostly on external factors to perform quality movement, such as vision, hearing, proprioception and others (Brakovska, 2010).

PNF stretching techniques are widely used in clinical settings to increase active and passive joint range of motion, improve muscle strength, flexibility and endurance to optimise movement performance and rehabilitation (Adler, Beckers & Buck, 2008).

The main goal of therapy is to restore normal motor control so that quality movements are restored sequentially based on the principles of normal motor development, which in turn will enable the patient to rehabilitate to the maximum possible level of functioning (Adler, Beckers & Buck, 2008).

Dorothy Voss points out that muscle synergy plays an important role in the development of movement as it ensures efficient and coordinated muscle action. Upper limb synergy is a complex process consisting of multiple muscles working together to provide efficient and coordinated movement. These muscles are involved in both stabilising functions and movement. The PNF technique is one way of improving the reflex ability of muscles and stimulating synergy (Voss, Ionta & Myers, 1968).

PNF is based on a number of key principles that improve neuromuscular response and functional performance. One of the principles is muscle irradiation, which involves the contraction of the strongest muscle group to stimulate the contraction of the weakest muscle group. Joint mobilisation is also used to improve joint mobility and range of movement. PNF techniques use patterning, which mimics functional activities and involves the coordination of several muscle groups. Patterns can be linear, diagonal, spiral, bilateral, and unilateral. Manual contact is important to provide feedback and facilitate the desired movement or stretch. Verbal instructions are used to help the patient focus on the desired movement or muscle contraction (Voss, Ionta & Myers, 1968).

Materials and Methodology

The review was planned and conducted in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines (Page et al., 2021).

In February 2023, the search and selection of studies in online databases such as PubMed, ScienceDirect, EBSCOhost, GoogleScholar, Cochrane Library, and Research Gate were launched. The systematic review included studies published between 2014 and 2023. Studies were searched using the keywords "Proprioceptive neuromuscular facilitation or PNF" with "post-stroke", "stroke rehabilitation", "upper extremity or limb", "hemiplegia", "spasticity", and "function" in various combinations.

The PICO model was used to formulate the research question that would determine the relevance of the articles and the limits of the study. The PICO model is the most commonly used model for structuring clinical questions, as it includes all the key elements required for the target question (Znotina, 2014).

The online reference organisation tool EndNote 20 was used to select the scientific articles.

The methodological quality of the studies included in the systematic review was assessed using the PEDro. The PEDro scale is currently used as a quality assessment tool for randomised clinical trials or controlled trials. The PEDro scale consists of 11 criteria, which are scored 'yes' or 'no' (1 or 0) depending on whether the criterion is explicitly met in the study. Low study quality is indicated by a score ≤ 3, fair study quality is indicated by a score of 4-5, good study quality is indicated by a score of 6-8 and excellent study quality is indicated by a score of 9-10, although it is important to note that this classification is not validated (Cashin, 2020).

Research articles that met all the following criteria were included in the review:

1) people with stroke - acute, sub-acute or chronic;
2) completed and available in full text format;
3) published between 2013 and 2023;
4) Design: randomised controlled trials, controlled clinical trials, and trials that include a before-after group analysis (without a control group);
5) PNF was applied as a physiotherapy method to improve upper limb function in patients after stroke.

Research articles were omitted from the analysis if they met any of the specified exclusion criteria:

1) Participants were less than 18 years of age;
2) were not available in English;
3) methodological quality score lower than 6 on the PEDro scale;
4) inadequacy of purpose and/or methodology.

Results

Results of the selection of studies

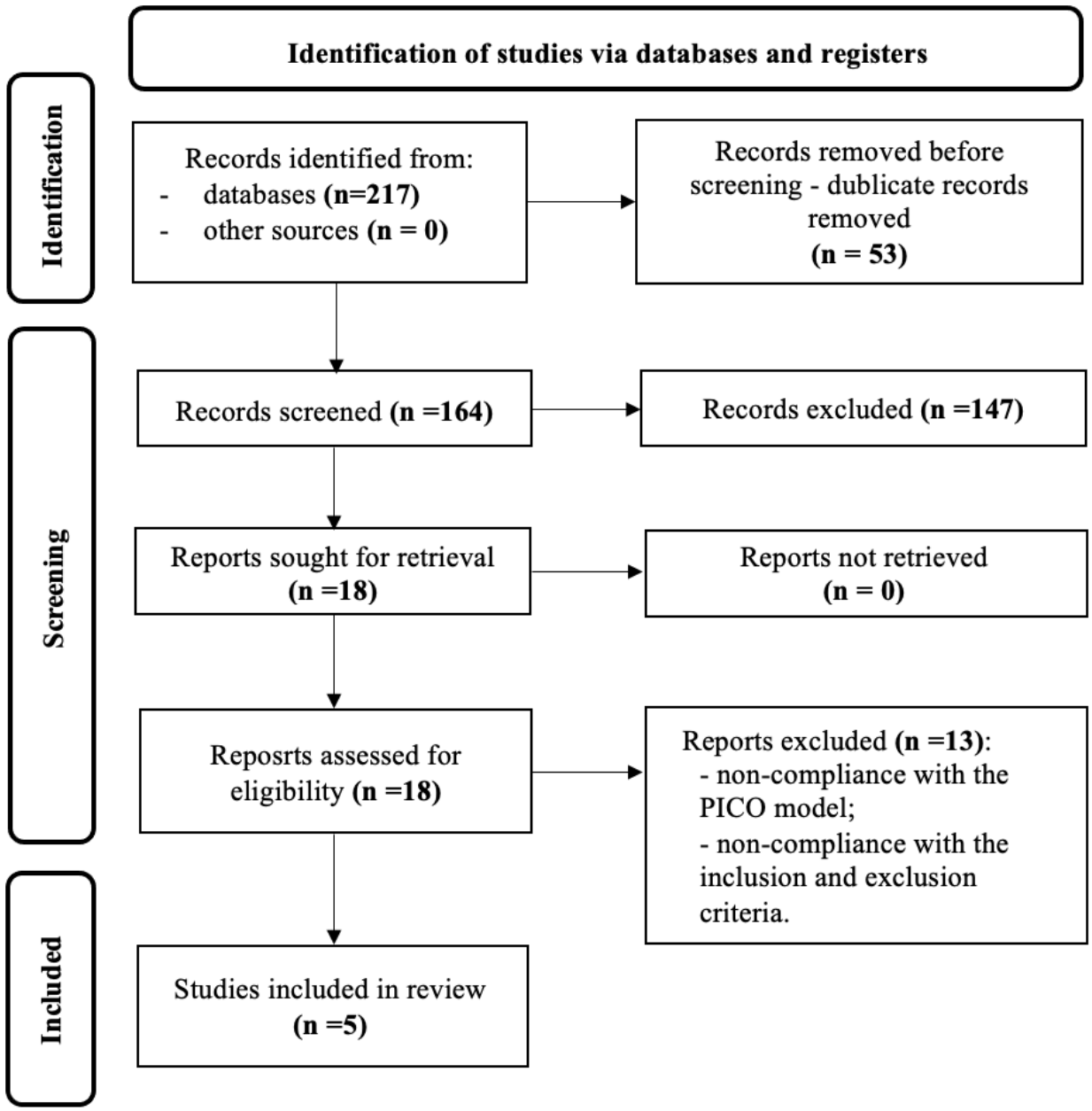

Figure 1 ***Flow diagram of article selection process*** *(Page et al., 2021).*

Table 1 ***Summary of included studies***

Authors	**1. Yeole et al. (2017)**	**2. Chaturvedi et al. (2018)**	**3. Santos et al. (2019)**	**4. Moraes et al. (2014)**	**5. Abba et al. (2020)**
Study design	Randomised controlled trial	Randomised controlled trial	Randomised clinical trial	Randomised controlled trial	A quasi-experimental clinical study involving a before-after analysis of two groups
Number of participants (intervention group/control group)	Total: 30 Experimental group - 15 Control group -15	Total: 90 Experimental group - 49 Control group -41	Total: 48 (40 analysed) Group 1 - 15 Group 2 - 11 Group 3 - 14	Total: 20 Experimental group - 10 Control group - 10	Total: 30 Group 1 - 15 Group 2 - 15
Average age of participants	58,06 (± 8,79) 59,73 (± 9,52)	61,30 (±13,30) 55,29 (± 15,90)	58,20 (± 7,70) 55,50 (± 9,60) 52,70 (± 13,30)	63,00 (± 9,16) 61,10 (± 5,72)	59.53 (± 9.92) 63.00 (± 7.27)
Stroke stage	Not mentioned	Acute or subacute (<6 weeks)	Chronic (haemiparesis lasting at least 6 months)	Chronic (more than 14 months)	Chronic
Type of therapy in groups	Experimental group: PNF method Control group: conventional physiotherapy	Experimental group: the PNF method Control group: Traditional exercises	Group 1: PNF method Group 2: VR method Group 3: PNF/VR methods	Experimental group: PNF method Control group: Conventional physiotherapy	Group 1: PNF method Group 2: CIMT method
Evaluation parameters and instruments	Ashford scale; Barthel Index; Upper and lower extremity range of motion	Fugl-Meyer Assessment; AMAT; BDNF	Fugl-Meyer Assessment	Fugl-Meyer Assessment; FIM;	Fugl-Meyer Assessment
PNF - Proprioceptive neuromuscular facilitation; AMAT- Arm Motor Ability Test; BDNF-Serum Brain-Derived Neurotrophic Factor; VR - virtual reality; FIM-Functional Independence Measure; CIMT-Constraint-Induced Movement Therapy.					

At the initial stage of study selection, 217 studies were identified in PubMed, ScienceDirect, EBSCOhost, GoogleScholar, Cochrane Library and Research Gate databases using selected keywords related to the PICO model elements, according to PRISMA 2020 guidelines. After a first filtering of the selected studies, 53 duplicate studies were excluded. For further review of the scientific articles, 164 studies were included, for which title and abstract matching was checked, resulting in 18 studies remaining. Further analysis of the full text of the studies according to the inclusion and exclusion criteria resulted in the exclusion of a further 13 studies. As a result, five publications that met all selection criteria were included in the systematic review and included in further analyses.

PEDro scale assessment of research quality

All full-text studies were assessed to exclude studies of low or average quality. All studies included in the review scored six or more on the PEDro scale.

Assessment of the effectiveness of the PNF method

Table 2 ***Mean AMAT score at before and after intervention Chaturvedi et al. (2018) study***

Study author, year	**Experimental group**		**Control Group**		***p - value****
	Before	**After**	**Before**	**After**	
	Arithmetic average				
Chaturvedi et al. (2018)	38,33 (SD±16,04)	92,40 (SD±24,60)	45,60 (SD±19,73)	75,73 (SD± 16,40)	0,038
* statistically significant differences between experimental and control groups; SD - standard deviation					

The Arm Motor Ability Test (AMAT), used by Chaturvedi et al. (2018), assesses upper limb functional capacity in people with neurological disorders. Table 2 shows the results of the upper limb motor ability and function assessment before and after the intervention Chaturvedi et al. (2018) study. The analysis of the results showed that the experimental group that was administered the PNF method had a greater difference in mean scores compared to the control group whose participants performed traditional exercises. When comparing the results of the two groups, the change in mean scores of the PNF group participants after the intervention was statistically significant ($p = 0.038$). However, no analysis of the results within each group was performed.

Table 3 ***Mean FMA upper limb motor function scores before and after intervention Santos et al. (2019) and Abba et al. (2020) studies***

Study author, year	**Group 1**			**Group 2**			***p - value****
	Before	**After**	***p - value***	**Before**	**After**	***p - value***	
	Arithmetic average						
Santos et al. (2019)	30,8 (SD±23,5)	33,8 (SD±24,7)	0,018	38,91 (SD±23,2)	43,8 (SD±23,7)	0,10	> 0,05
Abba et al. (2020)	34,4 (SD±9,76)	37,1 (SD±9,53)	0,000	36,8 (SD±7,63)	47,3 (SD±7,46)	0,000	0,002
SD - standard deviation; *statistically significant differences between different intervention groups; group 1 - PNF intervention; group 2 - other therapy							

Four out of five studies (Chaturvedi et al., 2018; Santos et al., 2019; Moraes et al., 2014, Abba et al., 2020) assessed upper limb motor function after Fugl-Meyer Assessment (FMA). Only the upper limb motor function score was selected from the four studies, with a maximum of 66 items. Table 3 shows the results of two publications (Santos et al., 2019; Abba et al., 2020) describing upper limb motor function after FMA. The overall result of both studies after the applied PNF intervention shows a statistically significant improvement in the mean scores ($p < 0.05$). In the control group, statistically significant improvements in mean parameters were observed in the study by Abba et al., (2020) ($p < 0.05$). In contrast, comparing the pre-and post-intervention results of the two groups, a statistically significant improvement in mean scores was observed only in participants in the Abba et al., (2020) study.

Table 4 ***Mean Ashford scale score before and after the intervention in the Yeole et al., (2017) study***

Study author, year	**Experimental group**			**Control Group**			***p - value****
	Before	**After**	***p - value***	**Before**	**After**	***p - value***	
	Arithmetic average						
Yeole et al., (2017)	2,46 (SD±0,51)	1,13 (SD±0,5)	<0,0001	2,40 (SD±0,50)	1,86 (SD±0,35)	<0,003	<0,0001
SD - standard deviation; *statistically significant differences between experimental and control groups							

Only one of the selected studies (Yeole et al., 2017) assessed participants' spasticity using the Ashford scale before and after treatment. The aim of the scale is to assess the degree of muscular resistance to passive movement in the joint at variable speeds. Table 4 shows the mean scores of the Ashford scale before and after the therapeutic intervention in the experimental and control groups Yeole et al. (2017) study. The data summarised in the table showed a reduction in spasticity in the upper limbs in both groups. The improvements in outcomes were statistically significant in both groups ($p < 0.0001$; $p < 0.003$). When comparing the mean scores of the two groups, participants in the PNF group showed statistically significant improvements compared with those in the control group ($p < 0.0001$).

Functional capacity for self-care was assessed only in Yeole et al. (2017) study using the Barthel Index. Table 5 summarises the average Barthel Index results for Yeole et al. (2017) study. When comparing the two groups' post-intervention scores, the PNF group was statistically significant compared to the control group ($p = 0.0164$). As well, participants in the PNF group showed statistically significant improvements in self-care ability after the intervention ($p < 0.0001$).

Table 5 ***Mean Barthel Index score before and after intervention in the study by Yeole et al., (2017)***

Study author, year	**Experimental group**			**Control Group**			***p - value****
	Before	**After**	**Before**	**After**	**Before**	**After**	
	Arithmetic average						
Yeole et al., (2017)	54,33 (SN±7,52)	85 (SN±5)	<0,0001	53 (SN±2,53)	79 (SN±7,6)	<0,0001	0,0164
SD - standard deviation; *statistically significant differences between experimental and control groups							

Changes in upper limb range of motion before and after the intervention were only assessed by Yeole et al. (2017) study. The study summarised the results of active range of motion changes in the shoulder joint in flexion, extension, abduction, internal and external rotation directions, in the elbow joint in flexion, and in the wrist joint in flexion, extension, radial and ulnar deviation directions, which were evaluated with a manual goniometer. There was a statistically significant difference in outcomes between patients in the PNF group compared with those receiving conventional therapy: improved shoulder flexion ($p = 0.0038$), extension ($p = 0.0468$) and abduction ($p = 0.0001$), elbow flexion ($p = 0.0042$) and wrist motion (flexion - $p = 0.014$; extension - $p = 0.03$; radial

deviation - $p = 0.0382$). However, no analysis of the results was performed within each group. A statistically insignificant difference between the experimental and control groups was observed when external and internal rotation of the shoulder and ulnar deviation of the wrist were assessed ($p > 0.05$).

Discussion

This systematic review included five publications that examined and evaluated the effectiveness of PNF in improving upper limb function in patients after stroke. Based on information from the PROSPERO international prospective registry of systematic reviews (National Institute for Health and Care Research), no studies similar or equivalent to this systematic review were identified. All studies included in the review scored six or more on the PEDro scale, indicating high quality studies.

In the systematic review, the total number of study participants was 210 patients, with the lowest number of participants in Moraes et al. (2014) study was 20 patients, and the largest number of participants was Chaturvedi et al. (2018) study -90 patients. The mean age of participants in the included studies ranged from 52 to 63 years. In the study by Santos et al. (2019), Moraes et al. (2014) and Abba et al. (2020) studies, patients were in the chronic stage of stroke, while Chatuverdi et al. (2018) in the acute or subacute stroke stage, but Yeole et al. (2017) study did not mention the stroke stage of the participants.

The authors of the study included in the systematic review, Yeole et al. (2017) had shown that PNF was effective in reducing spasticity, improving upper limb range of motion, and improving functional capacity for self-care. The other authors of the included studies, Santos et al. (2019), Abba et al. (2020), Chaturvedi et al. (2018), and Moraes et al. (2014) similarly demonstrated the statistically significant effect of the PNF method in improving motor abilities and function.

Upper limb motor abilities and function were analysed in four of the five studies using the Arm Motor Ability test and the Fugl-Meyer upper limb assessment. The studies showed statistically significant improvements in upper limb motor ability and function after PNF intervention. The aim of the study by Rai et al. (2015) was to demonstrate the effectiveness of kinesiotaping combined with PNF in improving motor function in patients with shoulder hemiplegia. The control group participants who had only PNF method applied also showed statistically significant results according to the Motor assessment scale ($p < 0.001$). Statistical analysis of the randomised controlled trial by Joshi and Chitra (2017) showed that the experimental group receiving PNF with conventional treatment and the control group receiving conventional treatment alone showed statistically significant improvement in motor function as assessed by the FMA ($p < 0.05$).

Functional capacity for self-care was assessed in only one study (Yeole et al., 2017). The aim of this study was to demonstrate the effectiveness of the PNF method in participants with hemiplegia, both participants in the experimental group to whom the PNF method was applied and in the control group showed statistically significant improvements in Barthel index ($p < 0.0001$). In the study by Borowicz et al. (2022), where the impact of PNF method and mirror therapy on the restoration of functional ability was compared among participants after their first stroke, both "before" and "after" intervention results on the Barthel Index and Rankin Scale showed significant improvements ($p < 0.001$).

Spasticity assessment of the upper limbs was performed in only one study (Yeole et al., 2017) using the Ashford scale. Based on the collected study results, a statistically significant reduction in spasticity was observed in both groups. Comparing the results of the experimental and control groups, a statistically significant difference was found ($p < 0.0001$). The results of Dhar et al. (2021) conducted a study evaluating changes in shoulder pain and spasticity in patients with hemiplegia using PNF techniques and stabilisation exercises; after 90 days, the mean modified Ashford scale score decreased in both groups: from 2.40 to 1.60 in the stabilisation exercise group, but from 2.93 to 1.53 in the PNF group.

Active range of motion assessment of the upper limbs was performed only in the Yeole et al., (2017) study participants using a manual goniometer. For the group of participants to whom the PNF method was applied, statistically significant improvements in mean scores were found in the direction of flexion, extension and abduction of the shoulder joint, flexion of the elbow joint and flexion, extension and radial deviation of the wrist ($p < 0.05$). Joshi and Chitra (2017) in their study involving patients with hemiplegia demonstrated that an experimental group that received PNF combined with conventional treatment had a statistically significant improvement in range of motion in the shoulder joint ($p < 0.05$), including external and internal shoulder rotation. In a study by Rai et al. (2015), another aim of which was to determine the efficacy of kinesiotaping combined with the PNF method in improving shoulder range of motion in patients with hemiplegia of the shoulder, the results of both groups showed a statistically significant improvement ($p < 0.0001$) in range of motion of the affected shoulder joint.

While this study provides valuable insights into the topic at hand, it is important to recognize its limitations, which may have influenced the results obtained. One of the main limitations of this study is the small number of included participants, making it challenging to confidently conclude the effectiveness of the PNF method in improving upper limb functions in post-stroke patients. The studies included in the review of the scientific literature had a wide variety of instruments used, so the comparison of the results of the studies was based only on the results of the FMA. However, the diversity of the study sample was limited by the fact that all included publications were in English only. Also, despite all

included studies scoring above 6 on the PEDro scale, four out of five studies did not use masking of raters, which may affect the objectivity of the results.

Based on the study limitations, recommendations for future research using PNF as an intervention can be made. It is recommended that studies use the same or similar main assessment tools to ensure comparable results and to facilitate data analysis and inference. In addition, the inclusion of a control group in all studies could increase the reliability of the studies and lead to stronger conclusions about the effectiveness of the method.

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